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# DELINEATING CATCHMENT AREAS FOR THE EASTERN EUROPEAN AIRPORTS IN 2010 - PRELIMINARY RESULTS OF THE ESPON DATABASE 2 M4D PROJECT –

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**Abstract:** This paper investigates the relation between the LAU2 centroids of selected countries in Eastern Europe and the closest airports, in terms of contribution to the construction of the theoretical catchment areas for these air nodes. Using time distances calculated in the road network and demographic mass of 2010, the methodology we propose is a reproductible guideline for the estimation of the relation between different geographical objects that match on an administrative geometry, at local level. Taking a conceptual distance to notions such as spatial accessibility or potential of interaction, we delineated the catchment areas based on the relative demographic contribution of the LAU2 to the construction of the airports' territorial service areas. The main challenge we faced is not the complexity of the model, but the proper estimation of the time distances in the road network and the implementation of cumulated population functions that can be mapped, in order to decline our objective - the territorial catchment areas of the airports.

**Keywords:** catchment areas, time distances, cumulated population functions, VIGO, LAU2

## I. INTRODUCTION

In the ESPON DATABASE 2 M4D Project, a specific work-package is dedicated to the construction of indicators related to the LAU2 geometry (local administrative units), for the countries included in the ESPON area of coverage. This task follows a methodology that is based on the evaluation of the relation between the LAU2 and the VIGO (very important geographical objects), the last one being a concept that includes a large variety of geographical features that defines the regional or national territorial endowment (airports, ports, cities of local or regional interest, universities etc.). Without intersecting the concept of spatial accessibility, the evaluation of this relation mobilizes the combination of different indicators, aiming to bring added value to the scientific knowledge of the regional territorial dynamics in Europe.

In this paper we focus on the methodological steps needed for the description and the explanation of the relation between the LAU2 and one VIGO, the airports. The study area is restricted to selected countries from Eastern Europe (Romania, Hungary, Czech Republic, Slovakia and Poland) for calculation purposes. Our intention is to delineate the airports' catchment areas, using distances and the demographic potential of the LAU2. In recent studies (Suau-Sanchez et al., 2014; Lieshout, 2012; Maertens, 2012), different methodological approaches were proposed, including the use of the Corine Land Cover demographic grids in the estimation of these areas. However, few studies include the administrative geometry of the LAU2, making thus the collection of indicators at this scale impossible.

In this article we develop a methodology that uses three steps in order to delineate these catchment areas, the first one consisting in the estimation of the distances towards the closest airport, the second one derives the cumulated population by these distances and the third disaggregating the catchment areas for each airport.

## II. LITERATURE REVIEW

There is an extensive literature relating to the accessibility of airports, as a result of the significance of this topic for researchers, policy makers, airlines and airports. A general definition of accessibility, given in the TRACC project of the ESPON 2013 Programme, is that accessibility represents “a construct of two functions, one representing the activities or opportunities to be reached and one representing the effort, time, distance or cost needed to reach them” (Spiekermann and Wegener, 2011), being a major factor of economic attractiveness of cities and regions (DSA et al., 2013).

Most of the studies insists on accessibility types and indicators, as crucial factors which influence passengers’ airport choice (Kouwenhoven, 2008; Reynolds-Feighan and McLay, 2006; Spiekermann and Wegener, 2006; Harvey, 1987). Koster et al. (2011), Harvey (1986), Skinner (1976) showed in their papers that the accessibility of airports in terms of travel time is determinant for the choice of an airport by air travelers, increasing the accessibility of an airport having beneficial consequences to improve its market position.

In spite of the studies focused on factors that drive passenger airport choice, the concept of airport catchment area is insufficiently debated. The Civil

Aviation Authority defines the catchment area analysis as "a way of estimating the geographic area from which a large proportion of an airport's outbound passengers originate from, or inbound passengers travel to, and their geographic distribution within this area" (CAA, 2011, pp.5).

The existing literature on airport catchment area highlights the importance of its size, being a crucial determinant of airport performance, in terms of its attractiveness to airlines, traffic throughput, connectivity and seat capacity offered (Suau-Sanchez et al., 2014; Maertens, 2012; Dobruszkes et al., 2011; Fröhlich and Niemeier, 2011; Malighetti et al., 2007; Malina, 2006). In dealing with this issue, there are several case-studies which calculate the potential size of the catchment area of various airports, whose results help policy makers in the forecasting of passenger demand (Lieshout, 2012; Niemeier et al. 2009; Malighetti et al., 2007; Pantazis and Liefner, 2006). Thus, Malina in his paper regarding the measurement of market power of the German airports has developed substitution coefficients in order to describe the share of the residents in an airport's catchment area for whom suitable alternative airports exists. He also emphasized the importance of the catchment area for the airlines, measured in population, gross value added, number of weekly flights and airline alliance connection (Malina, 2006). Another study centered on German airports belongs to Hancioglu, who among other things focuses on competition between airports and its effects on the aviation industry, highlighting the importance of the catchment area in airports economics (Hancioglu, 2008).

The literature dealing with airport catchment area size in terms of population usually take into considerations the NUTS 3 level in order to aggregate population values around the airport (Papatheodorou and Arvanitis, 2009; Grosche et al., 2007), recent studies using lower levels than NUTS 3, such as municipality level units (Redondi et al., 2013), or zip codes (Scotti et al., 2012).

## III. DATA AND CARTOGRAPHIC SUPPORT

The data we use in our analysis is provided by three sources of information: the ESPON Database Project, EUROSTAT and the ETIS PLUS Project. From the first data provider we have collected the geometries at LAU2 scale, a basemap that is published and constantly updated by the EuroGeographics Association for the administrative boundaries. In our case study, an option was made for the 2010 geometry, which matches almost perfectly with the most recent national census data (2011). All the other layers (NUTS3 and NUTS0) were derived from the LAU2 basemap by systematically dissolving the internal boundaries, in order to avoid scale mismatching of limits (see Table 1). A secondary basemap of the road networks for 2009 was also used in our analysis.

From this network we have estimated the time distances between the LAU2 centroids and the airports. The Eurotstat data provider allowed the demographic data collection of a harmonized dataset for 2010, at local level. The total amount of information concerns 17,989 spatial units for 5 countries: Czech Republic, Hungary, Poland, Romania and Slovakia. From the same source (Eurostat), a demographic layer with the estimated population in a 1km grid was also extracted. This grid was intersected with the LAU2 frame and the population for 2006 was summarized for each local spatial unit in our dataset. This intersection and collection of demographic information was necessary for a short time delineation of the demographic trends. The final data provider is the ETIS Plus Project, a sophisticated collection of tools and strategic data for policy designers. This source is the most reliable free data provider of information related to the European airports.

**Table 1** Data providers and sources of geometries

| Provider | Geometry | Data | Metadata |
|---|---|---|---|
| ESPON DATABASE 2 Project | LAU2 for 2010 | - | Complete |
| | Road network for 2010 | - | Complete |
| Eurostat | - | Population for 2010 | Not available |
| | Demographic grid for 2006 - 1km | - | Complete |
| ETIS PLUS | Airports location (2010) | Total passengers by airports (2010) | Complete |

## IV. METHODOLOGY

Several theoretical approaches are possible when delineating the catchment areas of the airports. The concept itself supports more interpretations and it is not easy to strictly define it. One simple approach is to overlay isochrones or distance limits on the spatial distribution of the potential clients. A more complicated way to map these client pools is to weight the airports with some indicators that describe their theoretical attractiveness in the territory (total passengers, number of direct flights or total connections from airport i to airport j). The solutions to this alternative approach are inspired by the gravity models (Huff model and Reilly's law of retail gravitation) or by models of potential of interaction. The main ingredients of these solutions are based on the mass of the airports and the distances between the clients and these facilities. These indicators are eventually weighted, in order to better capture the role of the distance decay and to better approximate the reality (Harvey, 1986; Grasland et al. 2007). However, the empirical validation is often difficult when data on flows towards the airports is missing. The solution we propose emphasizes not the airports as factors of attractiveness and as generators of flows, it focuses on the spatial distribution of the potential clients, at local level.

Our intention is to measure the amount of population available at local level and to relate this demographic mass with the distance towards the closest airport. Cumulating the population by time distance is the solution we propose because it can provide new information regarding the territorial role of airports for the areas they serve as transportation facilities.

The first step in our approach was to transform the road distances in km in time distances, which can approximate better the shape and the extension of the airports catchment areas. Using different speeds for each road category, we managed to create a reliable road network dataset and a time distance matrix. For the local roads we used 30km/h, for the regional segments 45 km/h, for the national roads 60 km/h and for the highways 90 km/h. These values were retained after an empirical validation of selected origin-destination routes in Romania, between Romania and Hungary locations and in Poland. The speeds we propose are subject to debate, especially for the local roads, a quantity of error that is impossible to evaluate being normal and acceptable, if one will take into account the spatial extent of the case study and the density of the road network we used.

Once the time distance matrix was created, we measured the distances between each LAU2 centroids and the closest three airports. Averaging these distances allowed us to create an indicator that can be mapped and illustrates the relation between the local administrative units and the interposed occasions represented by the airports.

Finally, cumulating the population by time distance towards the closest airport represents the basis of the indicator that describes the spatial extension of the airports catchment areas in the studied region of the Eastern Europe. However, this indicator can be locally disaggregated or regionally aggregated. These two possibilities imply separate approaches of the main concept - catchment areas. In a first case, we identify and map them using a regional context, in the second case we focus on each airport and we delineate the local service area for the airports present in the study area.

After sorting the LAU2 by a distance filter towards the nearest airport, the mathematical solution to the problem we propose is provided by the integrals of the LAU2 population vs. time distance:

$\int_i^j Pi\,dx$ ; in this case, i is the closest LAU2 to a given airport, j is the most remoted LAU2 and Pi represents their population in 2010. Implementing this solution in a GIS is a double option. Either one will choose an *if statement* in a spreadsheet, either an iterative tool or script, usable for the most common platforms.

## V. ANALYSIS

Mapping the average time distance to the closest three airports in selected countries of the Eastern Europe depicts a spatial pattern marked by moderate to high disparities. The LAU2 that create the most remote class (more than 3 hours average distance) represent 11 % of the total amount of local administrative units. They concentrate in Poland and Romania and they are less present in the three other countries (see Fig.1). As the calculus of the time distances ignored the national boundaries, the East of Hungary benefits from a fair access to air nodes. It would not have been the case, if the distance matrix was constrained by NUTS0 limits.

Five cities with regional polarization functions are situated in this red area - Bialystok, Lublin, Pecs, Galaţi and Brăila. Funded by the the European Regional Development Fund and the Regional Operational Programme 2007-2013, the airport of Lublin finally opened in December 2012. Another one is programmed to become operational in the proximity of Bialystok in 2015. These two air locations will definitely change the map of time distance for the Eastern Poland, reducing the territorial disparities mentioned before. In the same logic, an airport that will serve Galaţi and Brăilă should also have a consistent regional impact.

At the opposite, a fair average time distance to the closest three airports forms a spatial pattern that is specific to regions with good territorial endowment (airports, high speed road network and high density of the transportation infrastructure). This situation is present in Czech Republic and Slovakia, less visible in Romania or Hungary.

In the passengers' case, choosing between three airports is an option that links the concepts of territorial cohesion and regional or national endowment. For the economic actors that depend on the air cargo facilities, these isochrones are sometimes strategic because more options will limit the negative impact of the spatial monopole induced by the air nodes or the air operators.

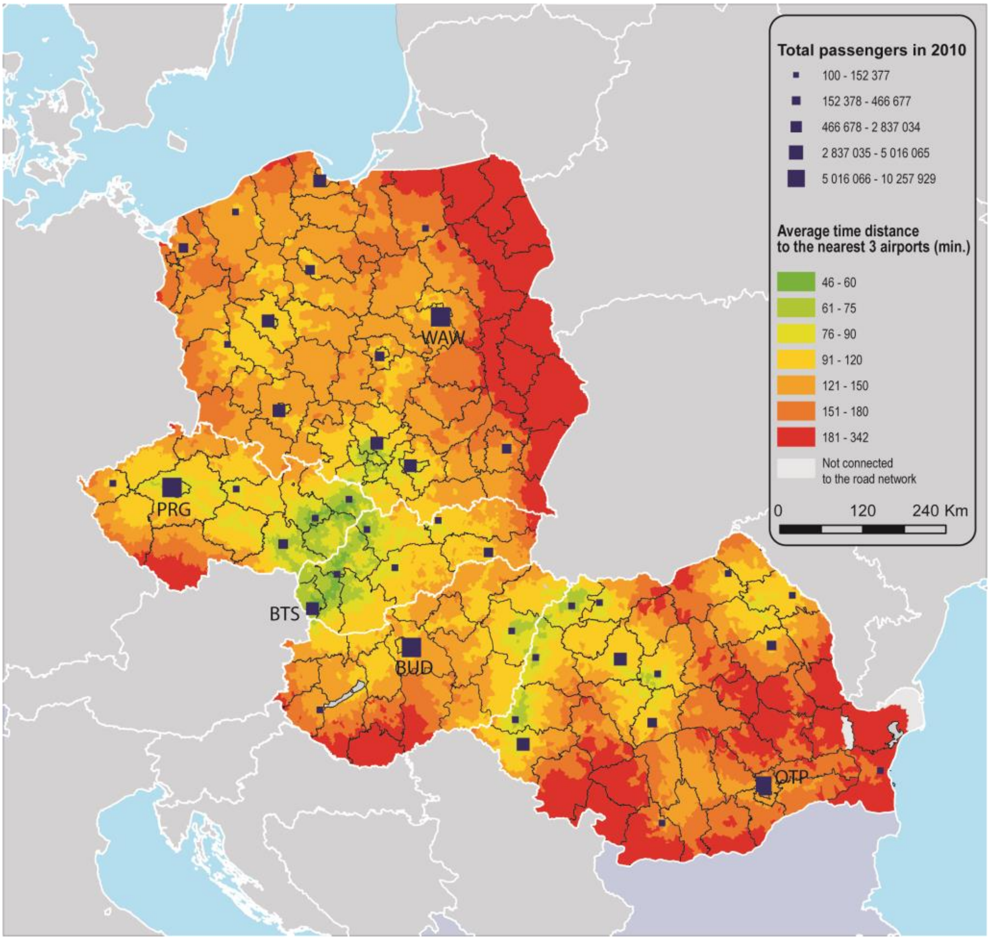


**Fig. 1** Average time distance to the nearest three airports in selected countries from Eastern Europe

The time distances to the airports are the first component for the delineation of the catchment areas. The second component is represented by the population in 2010. However, this indicator is not stable in time and the demographic context is a topic of major importance for a better understanding of how these catchment areas will evolve in time.

Using the time distance to the closest airport and the demographic evolution between 2006 and 2010, we propose a basic LAU2 typology that will place each airport and its catchment area in a territorial context. The map illustrates an intense West-East opposition, at regional scale of analysis. In Romania, for example, most of the airports dispose of service areas that are demographically declining (see Fig. 2). As the negative trend will most likely maintain, the catchment areas of the Romanian air nodes will probably shrink, excepting a steady situation of increase demand for air transportation. One of the consequences that can be imagined is also an increased competition between the airports with unpredictable impacts on the economic viability of some air platforms. In Czech Republic, Slovakia and Western and Southern Poland, the catchment areas of numerous airports present population growth for the analyzed period (2006-2010).

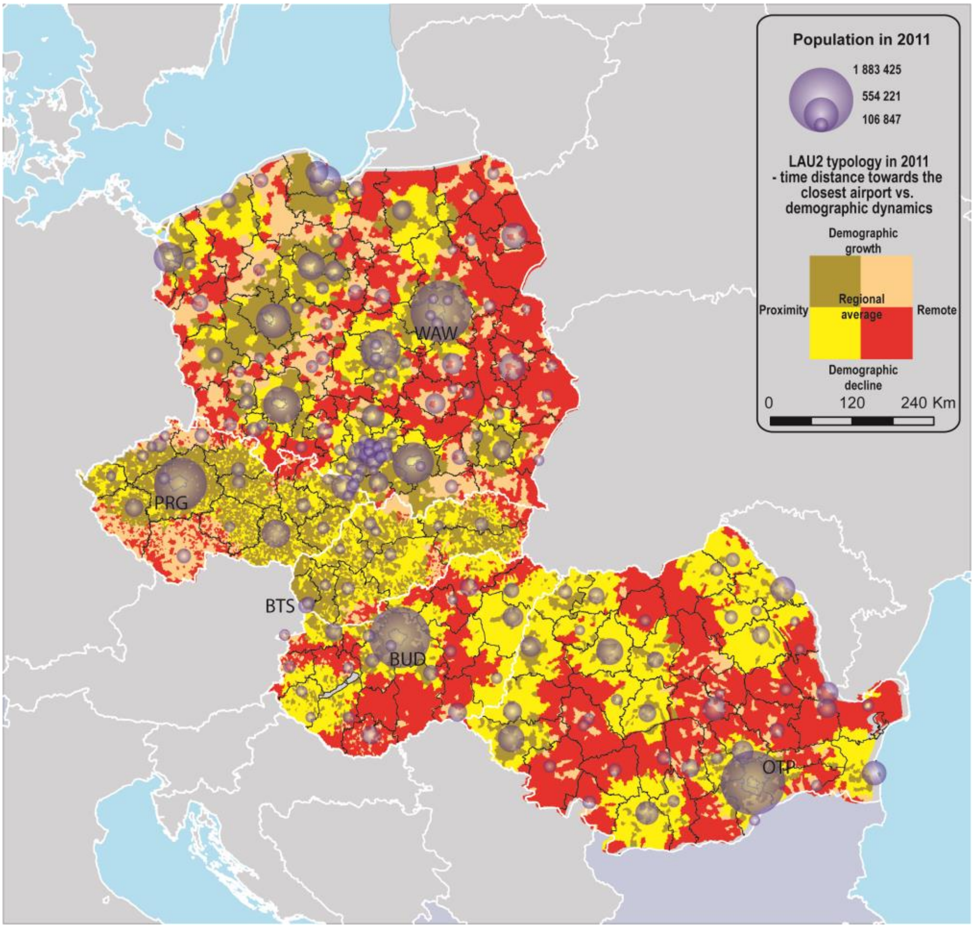


**Fig. 2** Demographic trends and time distance to the airports. The LAU2 typology for selected countries in Eastern Europe

Theoretically, their clients' pools are safer for medium or long term extrapolation, if we emphasize in our approach only the role of the local or regional demand for air traffic.

As the catchment areas of the airports are dependent on the time distances and the demographic context, a combination between these two indicators is possible using the cumulated population of 2010 by time towards the nearest airport. The result was transformed in relative values and serves as base for the cartographic depiction of the airports service areas (see Fig. 3).

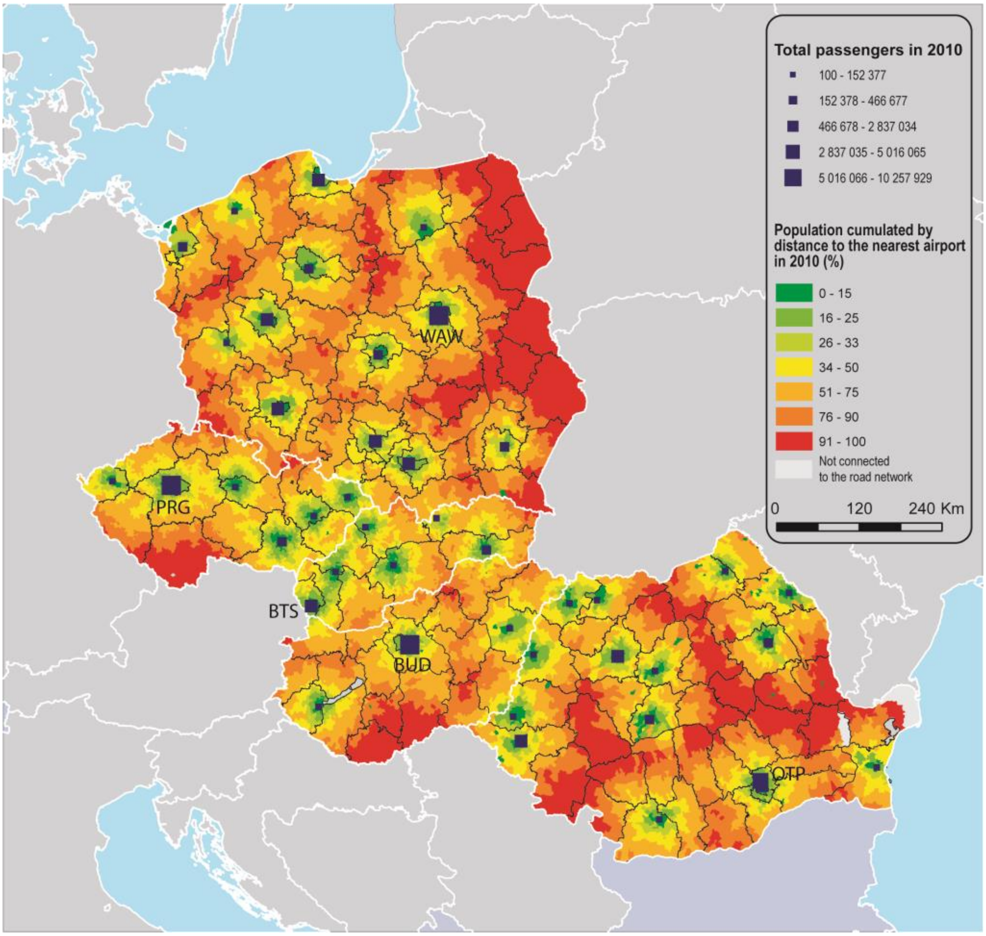


**Fig. 3** Population cumulated by time distance to the closest airport in 2010. An intermediate method to delineate airport catchment areas

Despite the obvious extension on the map, the last class of values will contain only 10 % of the regional population (about 8.2 million inhabitants in 2010). The time limit for this class is 130 minutes. In the same logic, 33 % of the population is situated at less than 45 minutes from the closest air facility and 50 % less than an hour. The role of the metropolitan areas and cities with regional functions is crucial in this distribution, as the airports are located in their proximity. In this problematic class of the legend there are few cities that demand the presence of an airport by their size and rank in the national urban systems - Bialystok, Lublin, Pecs, Braşov, Galaţi and Brăila. Affecting an airport to each of these cities will probably have a moderate impact on the distribution of the relative cumulated population.

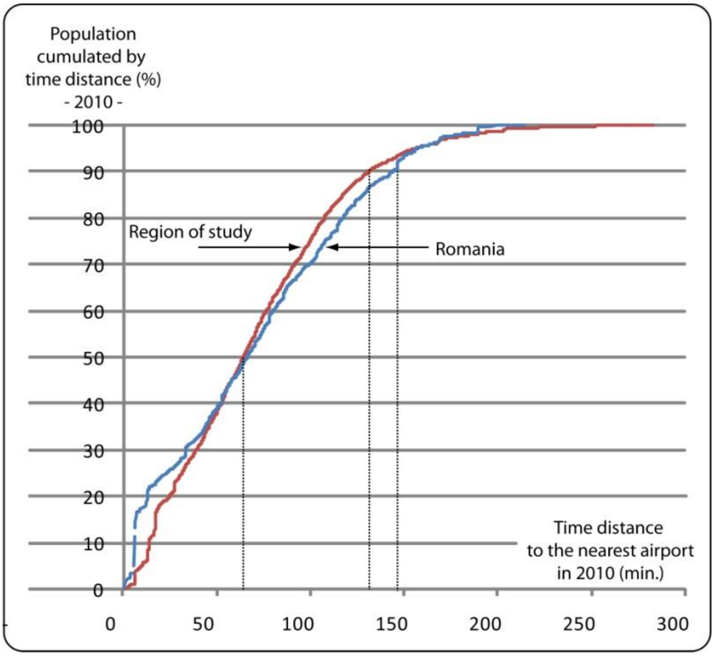


**Fig. 4** Population cumulated vs. time distance. Regional vs. national distribution

The interest of this method of delineation of the airports' catchment areas is double. Firstly, it serves as a tool of visualization, but it can also be transformed in a tool of territorial impact assessment, measuring the spatial effects and the increasing returns of new air infrastructure facilities. In the hypothesis that a new airport is located, the cumulated population will be shifted to the left. Using different territorial scales of analysis, this shift will estimate the amount of population that will benefit from a better access to airports. Applying this method at national scale shows that the spatial pattern of the cumulated population is strongly correlated with the urban hierarchy. In the case of Romania, the slope of the cumulated population function indicates some severe disparities (see Fig. 4). If for the first 50 % of the population the shape of the function suggests a better access to airports, compared with the regional trend, the other 50 % present a deviation to the right of the regional curve.

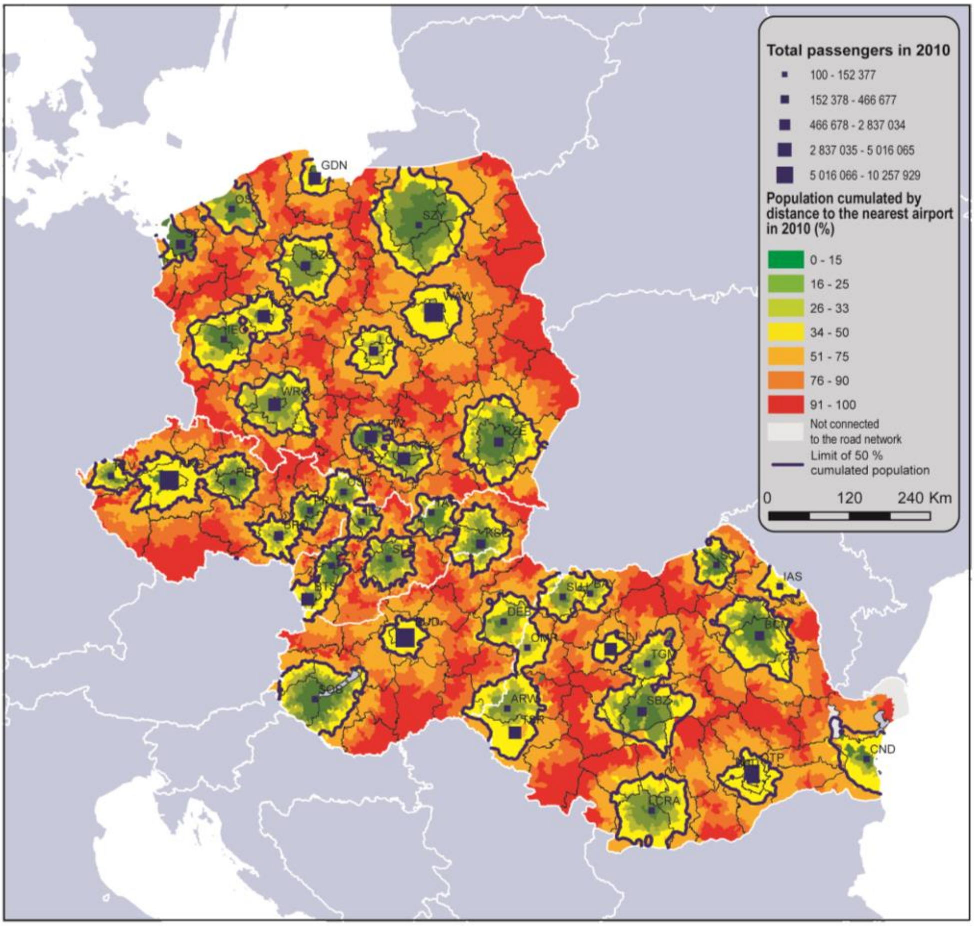


**Fig. 5** Delineation of theoretical catchment areas of Eastern European airports based on a 50 % isoline of demographic potential

Disaggregating this cumulated distribution for each airport implies a geoprocessing approach. Each pair of distances between i (any LAU2) and j (the closest airport to i) is filtered and a cumulative function that describe the demographic accumulation was implemented. In this case, we obtain for each LAU2 the relative share in the catchment area of an airport. Mapping these relative values is the most appropriate way to delineate the territorial service areas of the airports, emphasizing them by an IDW interpolation and contour extraction. In our case, we have made an option for the isoline of 50 % demographic accumulation (see Fig. 5). For airports placed near large metropolitan areas, the 50 % isoline creates a surface that is reduced. For airports closed to medium-size cities, the shape and the surface of the catchment area depends on the architecture of the territorial demographic system.

## VI. DISCUSSIONS AND CONCLUSIONS

In dealing with the estimation of the airports catchment areas, we investigated the relation between the LAU2 frame and the spatial distribution of the airports, in the studied area. Sorting the LAU2 populations by distance to the closest airports and transforming them into relative values, we managed to map the airports' territorial service areas at local level.

The approach we proposed opens the way to more elaborate analysis such as the multi-scalar typologies which can refine the understanding of the relation between the LAU2 and the airports. Delineating catchment-areas in a multiple territorial context and formalizing the interposed occasions as a constraint in our model serves as a tool of territorial impact assessment for decisions concerning the air traffic infrastructure.

As method and from a conceptual point of view, the frame of analysis we propose is a compromise between models of local accessibility for airports and theoretical models of spatial interaction. An empirical way to validate and consolidate this methodology is to have access to the data concerning the orientation of passenger's flows towards airports. The local flows and their frequency will eventually provide the coefficients needed to weight the distance decay functions used in our model.

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